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"Ionization Cross Sections for Neutral-Neutral Collisions Utilizing Asymmetric Charge Transfer"*

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Ionization Cross Sections for Neutral-Neutral Collisions Utilizing Asymmetric Charge Transfer*

A series of papers[1-4] has described the measurements of ionization cross sections σ_- for neutral atoms and molecules colliding with other neutral species at low energies. The technique of obtaining the neutral beam has been that of ionization in an electron-bombardment source, electrostatic acceleration and focusing, and neutralization of the ions by symmetric charge transfer. Essential to this procedure is the determination of the slow ion current formed in the charge transfer cell and the relationship of the slow current to the neutral beam intensity. This determination, and details of the apparatus, are described by Utterback and Miller.[5] The neutral intensity is believed to be accurate to about 20%, and ionization cross sections determined in this fashion are reproducible to 10% or better.

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*Supported by NASA Grant NsG-392

[1] N. G. Utterback and G. H. Miller, Phys. Rev. 124, 1477(1961).

[2] N. G. Utterback, Phys. Rev. 129, 219(1963).

[3] H. C. Hayden and N. G. Utterback, Phys. Rev. 135, A1575(1964).

[4] H. C. Hayden and R. C. Amme, Phys. Rev. (to be published, Jan. 1966)

[5] N. G. Utterback and G. H. Miller, Rev. Sci. Instr. 32, 1101(1961).

[redacted]

As long as the charge transfer cross sections are sufficiently large (i.e., comparable to or greater than the scattering cross section), one may expect to obtain a reasonably well-collimated beam. Cross sections[6] for the near-resonant ($|\Delta E| \lesssim 0.18$ eV) processes:

$$Ar^+ + N_2 \rightleftharpoons Ar + N_2^+ \qquad (1)$$

are of the order of 5 $Å^2$ at 40 eV and increase monotonically with energy in the range of interest, so that fairly good collimation is achieved for $E \gtrsim 40$ eV. The somewhat broadened spectrum[6] of slow ions from these asymmetric reactions imposes a limitation on absolute determinations, especially at lower energies.

With the use of neutral beams of N_2 and Ar formed by these near-resonant processes, we have re-measured the ionization cross sections for N_2 molecules on N_2 and for Ar atoms on Ar. These two cases are of particular interest because of the pronounced structure found for beam energies in the vicinity of 50 to 150 eV.[1,4] If, in the earlier work, collisions during the symmetric charge transfer process could have caused excitation of numerous beam particles to a metastable electronic state, e.g.,

$$\begin{aligned} \vec{N}_2^+ + N_2 &\rightarrow \vec{N}_2^* + N_2^+ \quad , \quad \text{or} \\ &\rightarrow N_2^+ + \vec{N}_2^* \quad , \qquad (2) \end{aligned}$$

then one should expect that the use of a different neutralizing gas should affect the measured cross section. In Figures 1 and 2, the solid lines are the ionization measurements utilizing symmetric charge transfer;

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[6] R. C. Amme and H. C. Hayden, J. Chem. Phys. <u>42</u>, 2011(1965).

the points are the new cross sections obtained using Reactions (1). It is seen that for both cases the general structure and details are preserved. Note that the abscissa is the energy in the center-of-mass coordinate system less the ionization potential. No significance can be attached to the departure at very low energies (less than ~40 eV) because of the rapidly decreasing charge transfer cross section, and the increasing difficulty of measuring beam intensities. The solid lines (symmetric charge transfer) represent the most reliable measurements. One sees that, over most of the curves, both types of measurements are in agreement to within $\pm 20\%$.

It would be quite fortuitous if the same metastable neutrals were to be created in the same abundance at different center-of-mass energies. For example, at 100 eV c.m. energy for argon neutrals on argon (200 eV beam and 84 eV plotted in Figure 2), the c.m. energies for the charge-exchanging collisions are 100 eV and 82 eV for Ar and N_2 neutralizing gases, respectively. We conclude that the ionization cross sections for these cases are largely characteristic of ground-state collisions. For measurements in which the target gas is much lighter than the incident neutral particle, the presence of any excited neutral beam component would be more readily observed, as seen from center-of-mass considerations.

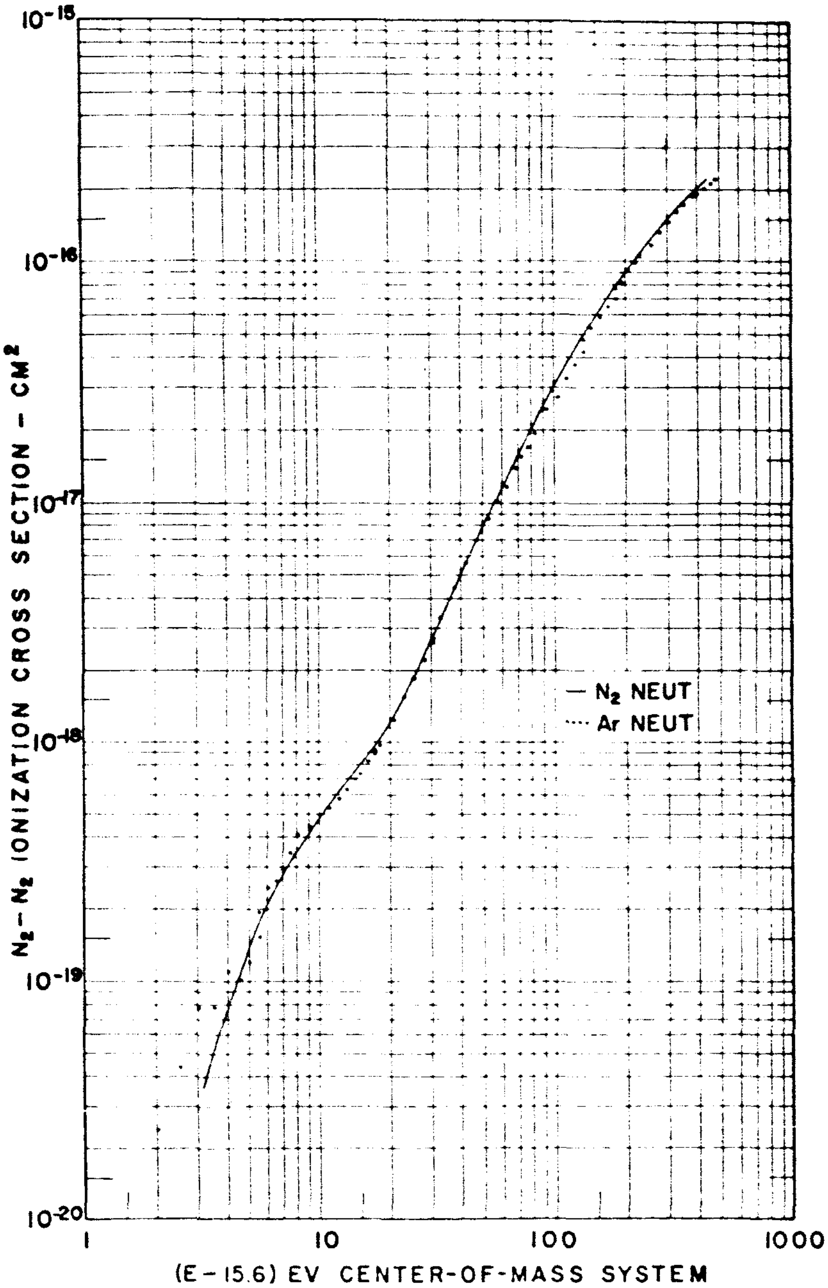

Fig. 1 Effect of Asymmetric Neutralization on N_2-N_2 Ionization Measurements.

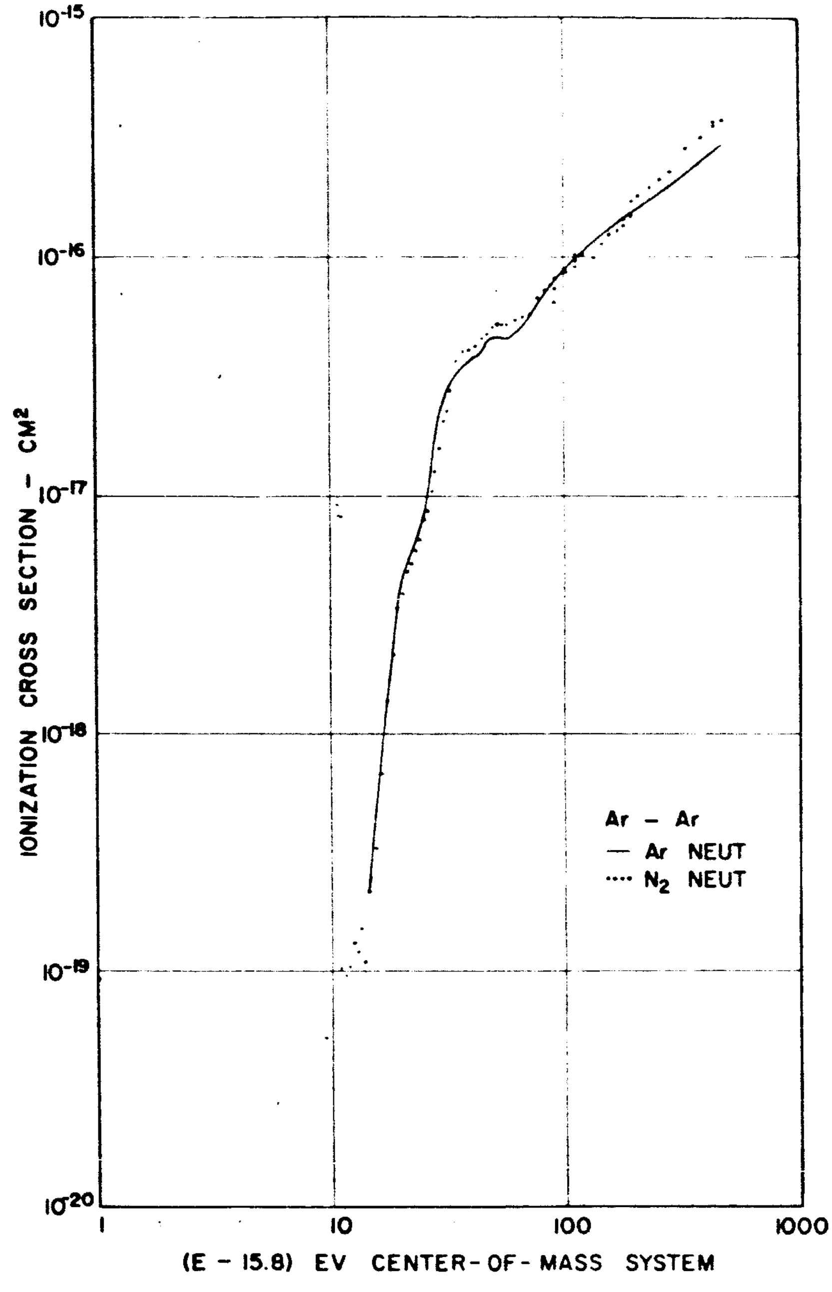

Fig. 2 Effect of Asymmetric Neutralization on Ar-Ar Ionization Measurements.